Synopsis V1.0

Single Event Latchup testing of the 512Mbit SDRAM from Maxwell

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1 Introduction

Single event Latchup (SEL) testing of the Maxwell 256Mbit (16Mx16) SDRAM was performed with heavy ions at Texas A&M Cyclotron Facility. This work was performed for the JWST project.

2 Tested Devices

Information about the tested devices is given in Table 1.

Table 1: Description of the tested devices

Type	? (no package marking)
Function	256M SDRAM
Package	74 pin ceramic flat pack
Technology	CMOS
Date Code	None (no package marking)

3 Testing Description

3.1 Irradiation conditions

The tests were performed at TEXAS A&M with 15 MeV/u beams. The parts were irradiated in air. The ions used and their characteristics are described in Table 2. The LET and range values given in Table 2 are the LET and ranges on the DUT.

Table 2: Ions used at TEXAS A&M

Ion	Energy (MeV/u)	Energy at target (MeV)	Range at target (? m)	LET at target (MeV-cm^2/mg)
Xe	15	1215	96	54.4
Kr	15	871	110	29.9

3.2 Test set-up and bias conditions

The test setup consists in a Heron FPGA module connected to the PCI bus of a PC via a PCI Heron module carrier. This setup has a capability of exchanging data with the memory bank at a rate of 500 Mbytes/s. The DUT replaces the original SDRAM bank of the FPGA module.

The DUT has its own power supply voltage. This bias supply voltage was set at 3.3V. When the DUT is in standby/quiescent mode the power supply current is about 9 mA. When the DUT is read or written into, the power supply current is about 70 mA. When the device is not in quiescent mode, but is not accessed, the power supply current is about 30 mA

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The device input current was monitored during the irradiation. In order to avoid destruction of the DUT in case of a radiation induced high current condition (single event latchup (SEL), single event functional interrupt (SEFI)), the DUT power supply voltage was shut down as soon as the input current reached a value larger than 100mA.

The DUT was heated with a thermistor, and the DUT package temperature was checked with a thermocouple. This allows testing the DUT sensitivity in the temperature range from room temperature to 85ºC.

The test sequence used for the test is a continuous sequence of write and read cycles. A test pattern is written in the memory, the memory is read, the errors are stored, and then the memory is written again. Because of contact problems between the DUT and the FPGA module, we were not able to write a test pattern into the memory and then read this test pattern without any errors. Therefore, it was not possible to perform SEU testing. However, the device was operated alternating write and read cycles during the SEL tests.

4 Results

The results of the SEL testing are shown in Table 4.

A summary of the results is as follows:

?? The SDRAM is sensitive to a high current condition for all LET values investigated (from about 30 MeVcm^2/mg to .78 MeVcm^2/mg) and all temperatures investigated (room temperature and 85ºC).

?? The SDRAM is more sensitive to high current condition at high temperature. However, the effect of temperature is not very significant except at the highest value.

A typical DUT current signature during irradiation is shown in Fig 1. Successive read/write cycles are performed. Then a high current condition occurs and the DUT power supply is shut down. During some irradiation runs, we can see, as shown in Fig 2, that the current signature shows some perturbations, probably indicating a Single Event Functional Interrupt.

We assume that the high current condition is due to a SEL. However, we cannot rule out the possibility of a SEFI causing this high current condition.

Table 4: test results

Run #	SN #	Pattern	Temp (ºC)	Ion	tilt	eff LET (MeVcm^2/mg)	eff. Fluence (#/cm^2)	SEL #	X SEL (cm^2/dev)
46	1	all0	room	Xe	0	54.4	1.32E+06	1	7.58E-07
47	1	all0	room	Xe	0	54.4	3.23E+06	1	3.10E-07
48	1	all0	room	Xe	0	54.4	5.45E+05	1	1.83E-06
49	1	all0	room	Xe	0	54.4	6.19E+05	1	1.62E-06
50	1	all0	room	Xe	0	54.4	1.09E+06	1	9.17E-07
51	1	all0	room	Xe	0	54.4	1.42E+06	1	7.04E-07
52	1	all0	room	Xe	0	54.4	6.76E+05	1	1.48E-06
53	1	all0	room	Xe	0	54.4	2.14E+06	1	4.67E-07
54	1	all0	room	Xe	0	54.4	7.56E+05	1	1.32E-06
55	1	all0	room	Xe	0	54.4	6.69E+06	1	1.49E-07
56	1	all0	room	Xe	0	54.4	6.04E+05	1	1.66E-06
58	1	all0	room	Xe	45	78.3	3.35E+05	1	2.99E-06
59	1	all0	room	Xe	45	78.3	3.11E+05	1	3.22E-06
60	1	all0	room	Xe	45	78.3	1.47E+05	1	6.80E-06
61	1	all0	room	Xe	45	78.3	2.68E+05	1	3.73E-06
62	1	all0	room	Xe	45	78.3	1.52E+05	1	6.58E-06
63	1	all0	room	Xe	45	78.3	6.74E+04	1	1.48E-05
64	1	all0	room	Xe	45	78.3	2.20E+05	1	4.55E-06
65	1	all0	room	Xe	45	78.3	2.06E+05	1	4.85E-06
66	1	all0	room	Xe	45	78.3	1.42E+06	1	7.04E-07
67	1	all0	85	Xe	45	78.3	3.85E+04	1	2.60E-05
68	1	all0	85	Xe	45	78.3	4.66E+03	1	2.15E-04
69	1	all0	85	Xe	0	54.4	1.89E+06	1	5.29E-07
70	1	all0	85	Xe	0	54.4	2.00E+06	1	5.00E-07
71	1	all0	85	Xe	0	54.4	4.91E+05	1	2.04E-06
72	1	all0	room	Kr	45	43.0	4.56E+06	1	2.19E-07
73	1	all0	room	Kr	45	43.0	9.46E+06	1	1.06E-07
74	1	all0	room	Kr	45	43.0	1.00E+07	0	0.00E+00
75	1	all0	room	Kr	45	43.0	2.93E+05	1	3.41E-06
76	1	all0	85	Kr	45	43.0	2.71E+06	1	3.69E-07
77	1	all0	85	Kr	45	43.0	2.67E+06	1	3.75E-07
78	1	all0	85	Kr	45	43.0	2.66E+06	1	3.76E-07
79	1	all0	85	Kr	45	43.0	3.25E+06	1	3.08E-07
80	1	all0	85	Kr	0	29.9	1.00E+07	0	0.00E+00
81	1	all0	85	Kr	0	29.9	1.12E+06	1	8.93E-07
82	1	all0	85	Kr	0	29.9	2.55E+05	1	3.92E-06
83	1	all0	85	Kr	0	29.9	1.00E+07	1	1.00E-07
84	1	all0	room	Kr	0	29.9	1.25E+06	1	8.00E-07
85	1	all0	room	Kr	0	29.9	1.00E+07	0	0.00E+00
86	1	all0	room	Kr	0	29.9	4.97E+06	1	2.01E-07
87	1	all0	room	Kr	0	29.9	1.00E+07	0	0.00E+00

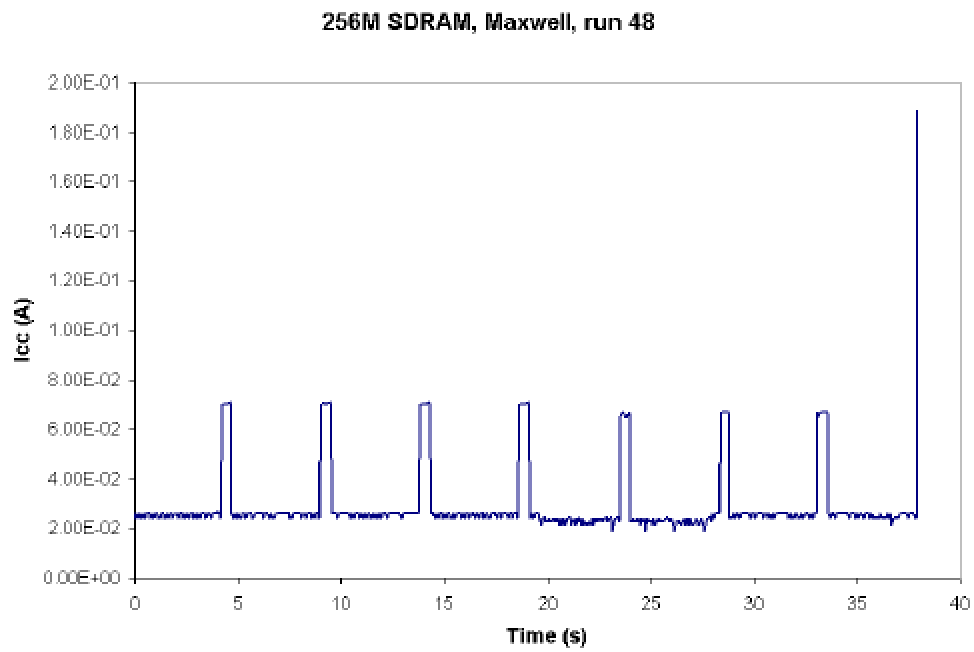

Fig 1: Current signature indicating a normal DUT behavior during irradiation before the high current condition

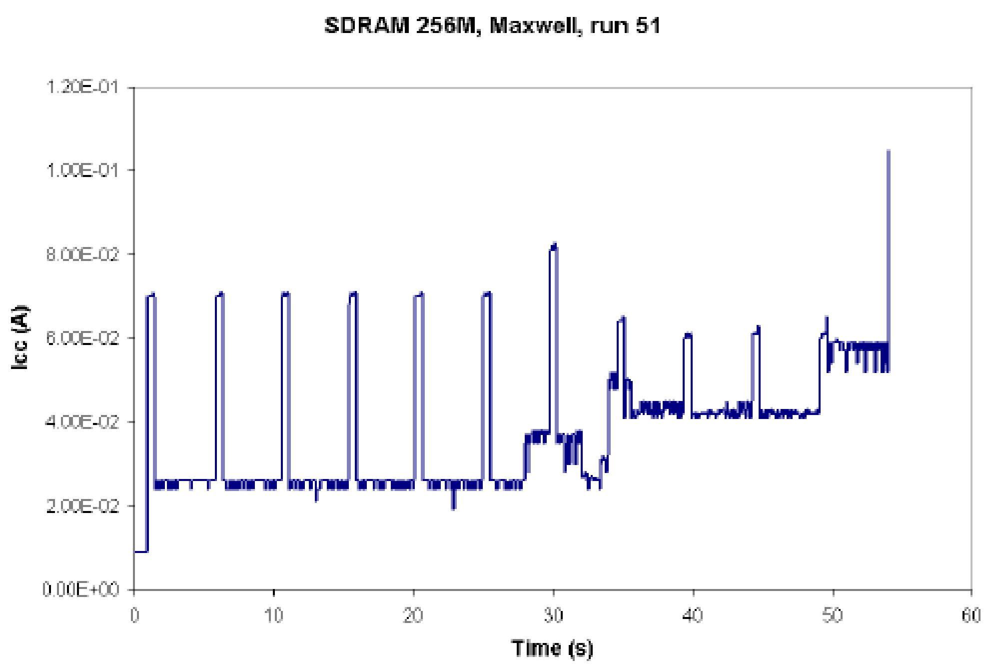

Fig 2: Current showing abnormal operating conditions before the high current event

Table 5 summarizes the results giving for each tested conditions the SEL average cross sections and the confidence limits. The confidence limits shown in the table represent the values of the cross section between which the true value of cross section lies within a 90% probability. These confidence limits have been calculated on the basis of a Poisson distribution with the following assumptions:

- only one event possible per incident ion,
- small probability of event.

Table 5: Summary of SEL results

Run #	Temp (ºC)	eff LET ($MeVcm^2/mg$)	eff. Fluence ($\#/cm^2$)	SEL #	X SEL (cm^2/dev)	90% Conf limit max (cm^2/dev)	90% Conf limit max (cm^2/dev)
80to83	85	29.9	2.14E+07	3	1.4E-07	3.63E-07	3.83E-08
76to79	85	43	1.13E+07	4	3.54E-07	8.11E-07	1.21E-07
69to71	85	54.4	4.38E+06	3	6.85E-07	1.77E-06	1.87E-07
67+68	85	78.3	4.32E+04	2	4.63E-05	1.46E-04	8.23E-06
84to87	room	29.9	2.62E+07	2	7.63E-08	2.40E-07	1.36E-08
72to75	room	43	2.43E+07	3	1.23E-07	3.19E-07	3.36E-08
46to56	room	54.4	1.91E+07	11	5.76E-07	9.54E-07	3.23E-07
58to66	room	78.3	3.13E+06	9	2.88E-06	5.02E-06	1.50E-06

Fig 3 shows the device SEL cross section curve.

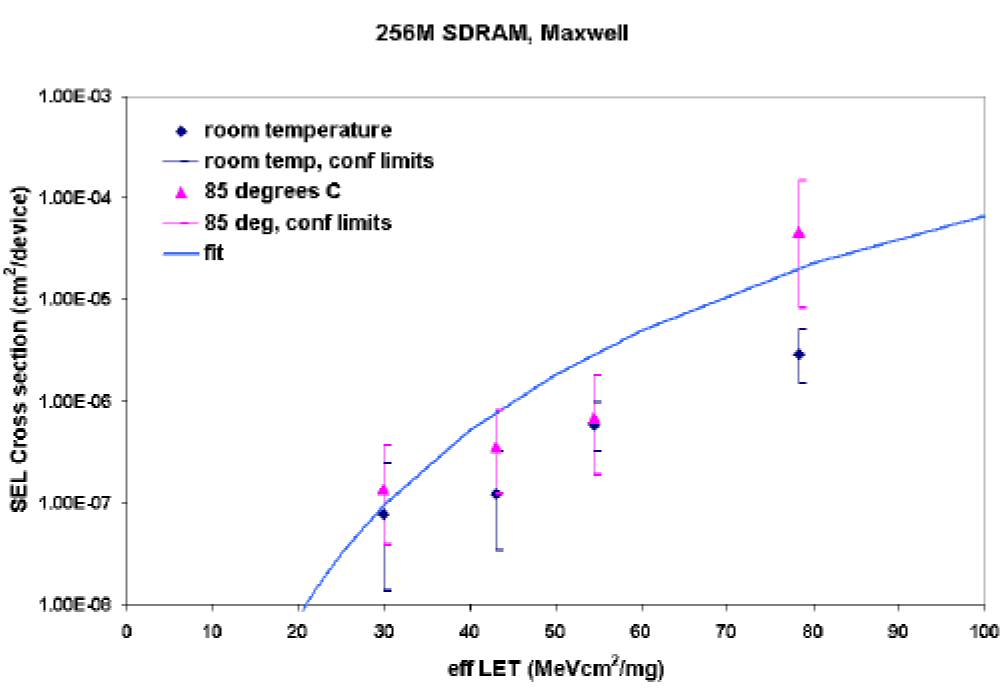

Fig 3: SEL cross section curve

5 Conclusions

The test results show a low sensitivity to SEL events with a LET threshold around 20 $MeVcm^2/mg$., and a worst case (max confidence limit) cross section of 1.5E-4 cm^2 device at a LET of 78 $MeVcm^2/mg$.